Pam:
622.24:
(*460)
HET

PD 6(4) Developments in Well Completion and Production
Techniques in Hostile Environments
(presented at the 10th World Petroleum Congress, Sept. 1979,
Bucharest, Romania)

OFFSHORE DRILLING AND PRODUCTION IN DEEP ICE COVERED WATERS

by C.R. Hetherington
L.J. Franklin

POLAR
PAM
4297

POLARPAM

OFFSHORE DRILLING AND PRODUCTION IN DEEP ICE COVERED WATERS

C. R. Hetherington, *President and Chief Executive Officer Panarctic Oils Ltd., 703–6th Avenue S.W., Calgary, Canada*; and L. J. Franklin, *Vice-President, Operations Panarctic Oils Ltd., 703–6th Avenue S.W., Calgary, Canada.*

Abstract. The Canadian Arctic Islands lie north of mainland Canada and they encompass an area of some one-half million square miles. Exploration activities have established the region to be prospective for hydrocarbon accumulations; some three-quarters of the area is under water exhibiting near permanent ice cover and water depths exceeding 400 m. The paper describes a procedure for the drilling and completion of offshore wells utilizing modified conventional land drilling rigs working from artificially thickened ice platforms. A system is described wherein a tubular bundle, consisting of flow lines and control lines, is connected to a subsea wellhead without the use of divers. Control and extended testing of the offshore well through the flowline bundle, which extends to a shore facility, has demonstrated a production system for subsea wells in ice infested waters. Two proposals for transport of gas to markets are reviewed. The pipeline proposal involves the crossing of several ice covered channels between land masses; suggested methods for laying the pipeline are discussed. The alternative method for gas delivery via year-round ice breaking LNG tankers is described.

Résumé. Les îles canadiennes de l'Arctique s'étendent au nord du Canada et elles couvrent une superficie d'un demi-million de milles carrés environ. Grâce à nos activités dans le domaine de l'exploration, nous avons prouvé que cette région est riche en réserves d'hydrocarbures; les trois-quarts environ de cette région sont en eau profonde de plus de 400 m couverte de glace en permanence. Cette communication présente une méthode pour le forage et la complétion de puits en mer qui consiste à utiliser des appareils de forage conventionnels pour le forage à terre modifiés qui permettent de travailler à partir de plates-formes de glace artificiellement épaissie. Nous décrivons un système qui permet de relier un ensemble de tubes comprenant des conduites d'écoulement et des conduites de contrôle, à une tête de puits immergée sans recourir à des plongeurs. Les contrôles et les tests complets de puits à travers l'ensemble de conduites d'écoulement, relié à des installations sur la côte, ont démontré la possibilité de ce système de production pour les puits sous-marines dans des eaux où le travail est rendu difficile par la glace. Nous étudions deux solutions pour le transport du gaz vers les différents marchés. Celle qui comporte le pipe-line implique la traversée de plusieurs bras de mer couverts de glace entre des étendues de terre; des méthodes possibles d'installation du pipe-line sont présentées. Nous décrivons également l'autre solution pour la livraison du gaz par des pétroliers brise-glace, navigant toute l-année et équipés pour le transport du gaz naturel liquifié.

1. SETTING

The Sverdrup Basin is a large hydrocarbon-bearing asin occupying a major portion of the Arctic Islands, hich lie north of the Canadian mainland about 000 km north of Calgary, Alberta (Fig. 1). The area omprises a frozen desert receiving only 6–12 cm of total recipitation annually. The land is permanently frozen a depth of up to one kilometer and, during a brief eriod in the summer, the top 30 cm or so melt, rendering e terrain impassable by wheeled vehicles. There is no ative habitation in the area of petroleum exploration perations. In the winter there is total darkness for three onths with temperatures ranging to −50 °C.

During a brief period in late August and early eptember the Arctic Ocean is navigable by ice reinforced hips escorted by ice breakers. The shipping route is 000 km from eastern Canada by way of Viscount Melville Sound to Melville Island. At all other times access to the Arctic Islands is by air only.

Exploration permits were issued covering major portions of the Canadian Arctic Islands in the early 1960s, and the first petroleum exploration drilling in the Arctic Islands followed shortly thereafter. To date, some $700 million has been expended in exploration with the drilling of some 140 holes. Large quantities of gas have been found (about 368 billion m^3) adding about 25% to the known gas reserves of Canada.

As in any frontier exploration effort, initial attention was concentrated on the large and easily accessible structures. As one might expect in an area 75% water covered, the principal accumulations of hydrocarbons were found to extend into offshore areas. Accordingly, there was generated a strong stimulus to develop an ability to explore the water covered areas which are ice covered all, or almost all, of the time.

Rec'd: Sept 11/81
Order No.:
Price: W1
Acc. No.: APOA Info. Service

BOREAL INSTITUTE
LIBRARY
46514

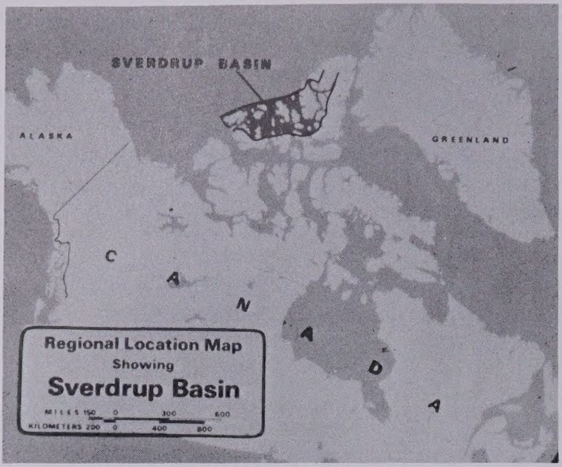

Fig. 1. The Sverdrup Basin. (Photograph courtesy of Panarctic Oils Ltd., Calgary, Canada.)

2. OFFSHORE EXPLORATION

As a first step in the undertaking to start offshore drilling from the ice, stations were set out on the ocean ice in 1971 to measure horizontal movement. The first measurements were made by conventional triangulation in the near shore area; the method was costly and was limited to line of sight. A more sophisticated system, utilizing a reference point on the ocean floor, interrogated by transponders, was later utilized as the distance from shore increased, making triangulation from shore-based points slow and difficult. At present horizontal ice movements are monitored by electronic devices which track the passing of satellites over the Arctic to accumulate data which provides the location of the receiving apparatus within a radius of one meter. Positions are recorded as satellites pass, and a near continuous record of ice movement is obtained. During the period from January to June horizontal ice movements have been within the limits that can be tolerated by the drilling equipment, namely an ice movement not exceeding 5% of water depth. It has now been established that ice platform drilling is physically possible between early January and mid-June. Ice platform drilling has been conducted each winter since 1973 to the present, and 13 ice platform wells have been drilled to date.

For initial drilling from ice platforms, land drilling rigs were modified to permit them to utilize a riser equipped with a single gate shear-ram subsea blowout preventer at the ocean floor, in conjunction with the traditional surface BOP stack. Following the installation of the drilling rig on the ice platform, and installation of the marine riser connected to the subsea blowout preventer, there is little difference from land drilling operations. Vertical movement due to tidal variations has insignificant effect on drilling procedures, but it must be accommodated in the support yoke for the riser tensioning device.

The results of early offshore drilling, combined with information obtained from seismic operations in the offshore area, reveal that much gas lies in the offshore area. Since many more millions of dollars must be expended on exploration offshore, it was deemed essential to develop the technology to demonstrate that a well can be completed offshore beneath the ocean ice, and connected to onshore production facilities by flowlines and control lines.

3. OFFSHORE COMPLETION

The initial requirement for such technological development was the design and fabrication of a more sophisticated ice platform drilling rig. In 1976, steps were taken to have designed and constructed a land-type drilling rig having many of the attributes of a conventional offshore floating drilling vessel (Fig. 2). The rig

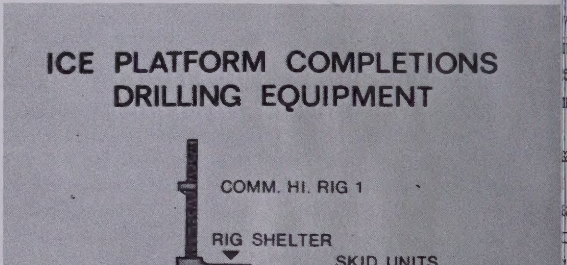

Fig. 2. Ice platform completions drilling equipment. (Photograph courtesy of Panarctic Oils Ltd., Calgary, Canada.)

as required to have the capability to accommodate a ıll subsea BOP stack and to complete a subsea well with ı ocean-floor wellhead. Irrespective of the capability to andle the large subsea equipment at the surface, the ansportability of rig and all equipment by Hercules rcraft could not be sacrificed. The rig, at 1.4 million kg, twice as heavy as any previously used for ice platform rilling, and accordingly it required a thick ice platform m) for its support.

In cognizance of the horizontal movement of the ice as critical parameter in ice platform drilling, the complete ıbstructure and derrick have been installed independent , and separated from, the other rig components. In vent of ice movement of up to 5 m the substructure can mounted on rollers and moved to maintain the derrick ertically over the hole on the ocean bottom.

The selection of a spot from which to demonstrate a ıpability to complete an offshore well and deliver its roduction to shore was the next step. One required the ssurance that the well would be a viable producer, and ıat the wellhead on the ocean floor would be below the ıreat of ice scour. Additionally, it was determined that e location must be reasonably close to shore and the ater depth must not exceed that providing reasonable ccess by divers. The completion and production system as designed to function in water depths beyond easy ver access and at long distances from shore, but for asons of economy and efficiency the location for ototype installation required the above latter attributes.

The Drake gas field, located on the east side of the ıbine Peninsula of Melville Island, has been defined by number of onshore and offshore wells and is known to ıve high productivity gas sands which extend to nsiderable distances offshore. Accordingly, a location as selected in the Drake field in some 45 m of water pproximately 1000 m from the shoreline. In January 78, the newly commissioned drilling rig, having pability to complete an offshore well, was placed on e ice at the selected location and drilling and completion a development well in the Drake field proceeded. The ell was completed with large diameter tubing to permit gh flow rates. Downhole equipment included a packer ıd an automatic subsea safety tubing valve, plus special vices to provide annulus access to the tubing string in e lower portion of the hole for the introduction of glycol inhibit hydrate formation.

The wellhead is controlled by a hydraulic subsea ntrol system mounted on the subsea wellhead. By ilizing the hydraulic control system provided for the bsea BOP stack, rig floor control of all subsea functions available for completion/workover operations. Upon moval of the drilling rig, control of the subsea wellhead effected from shore-based facilities via two hydraulic ntrol lines incorporated in the flowline bundle. A quential hydraulic system permits the eight separate ellhead functions to be controlled independently.

The drilling and completion of the well was conducted a routine manner without the use of divers. The operational procedures and the equipment utilized are applicable in all depths down to 400 m of water, the deepest waters in which Arctic Island exploration now extends.

Operations described to this point have been essentially modifications of existing offshore procedures which are routinely conducted from conventional floating drilling vessels throughout the world.

4. FLOWLINE CONCEPT

For the installation of equipment to control the under-ice subsea completion, and to deliver the production to shore-based facilities, new procedures and concepts had to be developed (Fig. 3). It was early apparent that conventional pipelay equipment would be inapplicable because of the ice cover. To assess alternative means of installation, studies of ice thickness and strength were conducted; these revealed that land-based pipelay equipment could operate from the ice surface. The low lateral forces that could be withstood by the wellhead pile, combined with the requirement to demonstrate a system applicable to 400 m water depths, ruled out laying the pipe back from the wellhead. The most attractive alternative appeared to be a bottom-pull installation using the ice as a stable platform from which to pull the flowline, which would be fabricated on shore.

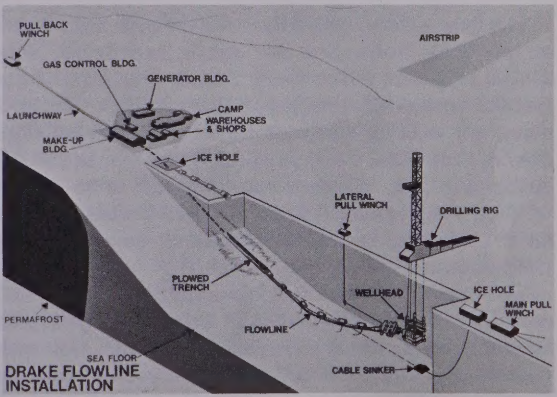

Fig. 3. Flowline installation.

The most promising method for connection of the flowline to the wellhead was determined to be by lateral pull of the outer end of the flowline bundle to deflect it like a large spring to facilitate connection with the wellhead.

5. FLOWLINE INSTALLATION

The design and installation of the flowline was subject to the approval of the Department of Indian and

Northern Affairs. The relevant standard was CSA Z-184, 'Gas Pipeline System'.

The bundle (Fig. 4) consisted of a 457 mm carrier which enclosed two 168.3 mm flowlines (each independently capable of handling the predicted gas flow of 70 800 m^3/h) plus a 60.3 mm line for access to the well annulus, a 33.4 mm line for glycol injection and two 33.4 mm lines for hydraulic control functions. The internal components of the bundle were supported at 6.1 m intervals by cast aluminum spacers.

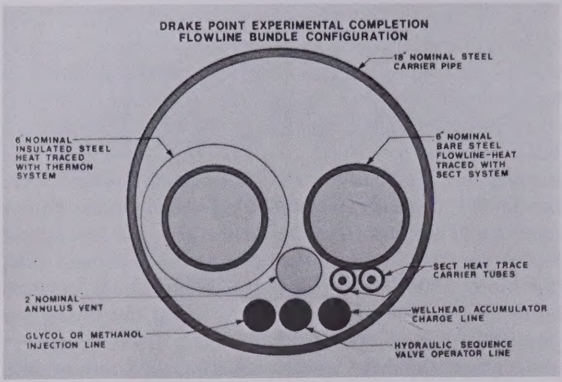
DRAKE POINT EXPERIMENTAL COMPLETION
FLOWLINE BUNDLE CONFIGURATION
18" NOMINAL STEEL CARRIER PIPE
6" NOMINAL INSULATED STEEL HEAT TRACED WITH THERMON SYSTEM
6" NOMINAL BARE STEEL FLOWLINE-HEAT TRACED WITH SECT SYSTEM
SECT HEAT TRACE CARRIER TUBES
2" NOMINAL ANNULUS VENT
WELLHEAD ACCUMULATOR CHARGE LINE
GLYCOL OR METHANOL INJECTION LINE
HYDRAULIC SEQUENCE VALVE OPERATOR LINE

Fig. 4. Flowline section.

The field welding procedures for the pipe were based on previous North Sea and Arctic experience, with special reference to the Trans Alaska Pipeline and det Norske Veritas rules for submarine pipelines. Shielded metal arc welding was used throughout with cellulose coated electrodes of a type specially developed for the Alaska Pipeline. The steel was preheated to 95 °C and welding was conducted in an enclosed heated environment consisting of a tent maintained above freezing temperatures.

The combination of flowline bundle, wellhead and downhole casing was regarded as a single unit protected by sacrificial anodes at the wellhead in conjunction with protective coatings on the wellhead structure and the flowline bundle.

The pipes inside the bundle were coated as a protection should the 457 mm casing become flooded during operational life of the installation. Field experience has shown that the selection of plastic coating for Arctic application merits considerable attention. Substantial damage was suffered by the polyethylene shrink sleeves due to local failure at −30 to −40 °C, when the small support rollers tended to freeze, causing abrasion and local cutting of the coating. Prior to future installations, comprehensive low temperature testing of coatings and the selected roller supports will be necessary.

Essentially all of the operation of fabricating the flowline bundle was performed in the heated fabrication shop. As the fabrication proceeded, the assembled bundle was progressively moved up the launchway extending shoreward from the shop. As the interior lines were pulled into the 457 mm carrier, the winch pull increased more rapidly than anticipated. In order to prevent distortion and jamming in the pipe, large quantities of hydraulic fluid were added as a lubricant, limiting the maximum pulling force experienced to 520 kN.

Following completion of the flowline bundle, the subsea completion manifold (SCM) (Fig. 5) was brought into the fabrication shop and connected to the outboard end of the flowline bundle. All lines were tested to full design test pressures, and the flowline bundle was ready for installation.

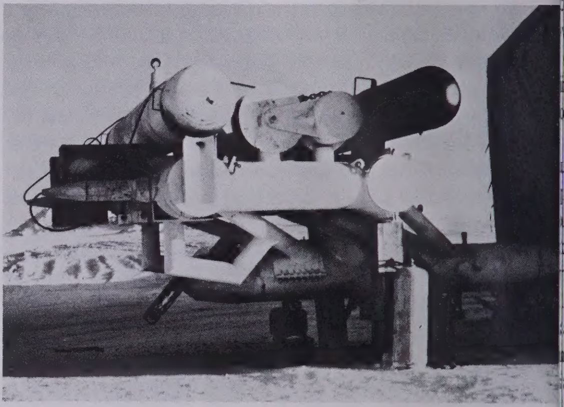

Fig. 5. Subsea completion manifold (SCM). (Photograph courtesy of Panarctic Oils Ltd., Calgary, Canada.)

6. MAIN WINCH

The winch, having a bare drum pulling capacity of 84 kN and a drum capacity of 1646 m, was initially installed at the shoreward end of the flowline launchway to assis in assembly of the flowline bundle. Following completion of bundle fabrication, the winch was moved to a artificially-thickened ice platform in line with the flowline pull and 1440 m from the shoreline.

The original plan to bring the winch cable back t shore by cutting a continuous ice trench was modifie because the ice was 7 m thick where the cable passe below the platform supporting the drilling rig. Three ic holes were cut around the edge of the ice platform an divers passed a light polypropylene line under the ice Heavier lines were progressively pulled under the ic until the main 50.3 mm wire rope could be handle safely. The procedure worked well and established tha a team of divers can rig heavy winch cables for substantia distances under the ice without the necessity of ic trenching.

7. SHORELINE CROSSING

Construction of a marine pipeline in the Arctic ɛvitably involves protection of the pipeline from ice at ɛ shore crossings and in near-shore regions. Following analysis of ice conditions in the Drake area, it was ncluded that there was no risk of icebergs, but there ıs a low probability of ice islands entering the channel d scouring the seabed at water depths of 25–40 m. :cordingly, the wellhead had to be positioned below ıs potential hazard.

For water depths of 20 m and less, a high frequency of ttom scouring by ice keels was anticipated. A seabed rvey revealed that the sea bottom was exceptionally ft and it became clear that the depth of a stable open nch in which to bury the pipe was limited to about 5 m, regardless of the size of the plough or power ailable. The decision was taken to bury the pipe only the 20 m water depth, on the premise that any ice mass th sufficient draft to scour bottom beyond such depths ould destroy the flowline, regardless of burial.

Following acceptance of a limitation on the available rial depth, further action was required to protect the pe against ice impact. The method selected was to fit ɛ buried pipe with a refrigerated jacket which would tract heat from the surrounding soil to build an tificial layer of permafrost around the pipe. Some 2 m of the flowline bundle were surrounded by 610 mm ameter casing jacket through which was circulated a illed mixture of 50/50 methanol and water. A refrigeration plant, rated at 117.15 kW was installed at shore maintain the circulating fluid at −32 °C.

The refrigeration process was designed to provide a ozen zone some three meters in diameter following the tial 60 days of operation. The flowline bundle, rrounded by the frozen soil, was analyzed for resistance a number of modes of loading due to ice impact. The alysis indicated that the probability of survival of the wline bundle was improved substantially by the freeze-ck system. Following generation of the initial frost lb, operation of the refrigeration unit can be conducted clically to provide maintenance of a frost bulb of the sired diameter. Strings of thermistors were installed at veral stations along the near-shore portion of the peline to monitor the extent of frost buildup.

8. TRENCHING PLOUGH

The general concept of a seabed plough capable of ble operation was available from previous experience trenching marine pipelines. The seabed plough (Fig. was specially designed and developed to operate in the y soft material at the chosen site. Large skids were ɛd to carry the weight of the front of the plough and ge floating or pivoted mould boards were fitted to carry spoil well clear of the trench to prevent loading of the nch walls.

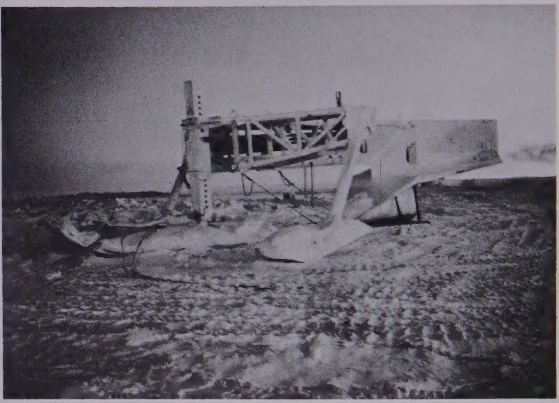

Fig. 6. Seabed plough. (Photograph courtesy of Panarctic Oils Ltd., Calgary, Canada.)

The design was developed on the basis of $\frac{1}{10}$ scale model tests conducted in the mud flats in Essex, England, followed by laboratory tests of the same model at Newcastle University using specially prepared soils. The complete plough was nearly 20 m long and weighed 26 400 kg in air. The full size plough was tested at Steveston Channel near Vancouver in soil conditions similar to those at the Arctic site prior to air shipment to location in December 1977.

9. PLOUGH OPERATION

The plough was placed on the ocean bottom in 7 m of water through a large hole in the ice and attached to the main winch cable by divers. Following a short pull (30 m) of the plough to check trench depth, the plough was trimmed by flooding the ballast tanks and then pulled the full distance out to 20 m water depth at a rate of 10 m/min. Diver inspection and electronic underwater survey subsequent to the ploughing operation indicated that a stable trench of 1.5 m had been produced. Following completion of the trench, the plough was moved to one side of the right of way and supported under the ice for later recovery following completion of the main flowline placement.

10. MAIN PULL

Prior to completion of the main pull of flowline bundle to its permanent position on sea bottom, the forward 300 m section of the bundle was floated in a trench cut in the ice to adjust the ballast in the buoyancy tanks (Fig. 7) for fine control of the buoyancy. While floating in the trim trench chain ballast was added to result in a weight/buoyancy ratio which would maintain the outward 300 m of pipe at 3–4 m above the ocean bottom. In future operations it is probable that the slow and difficult

Fig. 7. Buoyancy tank with underwater navigation transponder.

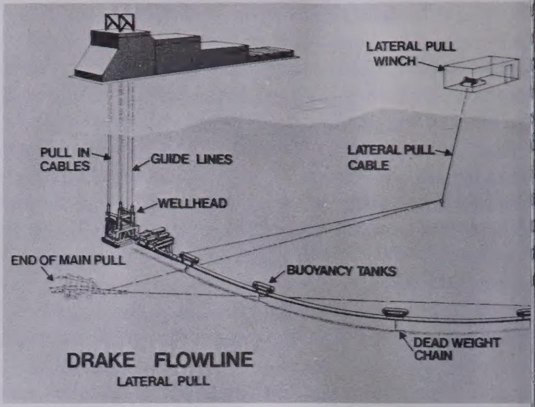

Fig. 8. Lateral pull procedure.

trim trench operations will be eliminated. Experience with divers on site has indicated that required buoyancy could be obtained more easily by controlled evacuation of the buoyancy tanks with the pipe resting on bottom in shallow waters. Such procedure would eliminate the long and difficult trim trench, permitting the pipe to be introduced into the water through a relatively small hole in the near-shore ice.

Following completion of the buoyancy trimming operation the pipe was pulled to resting place with the outer end of the pipe placed in a target area some 50 m from the subsea wellhead.

Upon confirmation that the pipe had been placed in the desired position, and that the near-shore section was resting properly in the trench, backfill was conducted with trucks depositing gravel on the ice adjacent to the trim trench. Dozers were utilized to push the gravel into the trim trench for completion of the backfill operation.

11. LATERAL DEFLECTION

Model testing had been utilized to establish criteria for a lateral pull procedure (Fig. 8) to mate the end of the flowline to the subsea wellhead receptacle. All portions of the concept were to be compatible with remote diverless operation, which might be extended to water depths of 300–400 m without significant change in technique. A simulation model was prepared to determine the practical and technical aspects of a lateral pull procedure, utilizing a wire of appropriate weight and stiffness to simulate the flowline bundle. The model work showed that a lateral pull winch, applying a force diagonally backwards, would cause the flowline to deflect toward the wellhead and simultaneously go into a column bending mode. By appropriate positioning of the lateral pull winch the outer end of the flowline could be placed in a position some 3–4 m from the wellhead. To improve control under field conditions, a second winch was added on the opposite side to apply an offsetting tension as
required. The model tests confirmed that the lateral
could be achieved in all reasonable combinations
bottom friction and current velocities. The indica
maximum winch loads were below 40 kN and
bending stresses in the pipeline were within the limit
Code CSA Z-184. During the deflection operation,
highest stress situation was predicted to be 90% of yi
in the 457 mm carrier pipe and substantially less in
internal flow lines. In the final installed condition it
evident that the combination of pressure and bend
stresses would be comfortably within the limits allow

12. UNDER-WATER NAVIGATION

Coincident with the lateral bending operation a s
of nine transponders installed on the buoyancy ta
were interrogated and located relative to fixed refere
transponders previously installed on the seabed.
information obtained was displayed on a digital print
and on an XY plotter, to provide continuing assura
that no sharp bend nor unacceptable stress concentrat
was being developed in the flowline.

The deflection was completed in approximate acco
ance with the prepared procedure, taking about f
hours to bring the flowline to the required position bef
the wellhead, in plain view of the underwater
cameras. The flowline position, the winch loads,
cable travel were each in close agreement with
predicted values based on model studies. At no time
there indication that the flowline was under excess
load or unacceptable bending stresses.

13. FINAL MATING

With the subsea completion manifold (SCM) dire
in front of the wellhead, two buoys were electronic
released from the SCM to carry cables to the unders
of the ice for recovery by divers. The cables were

ough guide pulleys in the wellhead pull-in frame, and frame was lowered on the guidelines and positioned the subsea wellhead. To achieve final mating the two eral pull winches were paid out and the pull-in cables re tightened to effect the final tie-in. The end of the wline was always under close control with no possibility unexpected surge or rapid movement that might mage the wellhead. The pull-in cables insured that a nnection could be effected in spite of misalignments in horizontal and roll planes. Maximum tension on the ll-in cable was 50 kN.

14. HEATING AND INSTRUMENTATION

One objective of the experimental flowline installation s to evaluate two different designs for flowline heating. ch of the two 168.3 mm flowlines were equipped with eating system to provide a means of clearing hydrate cumulations or ice plugs.

One system, representing the more traditional or nservative heating system, consisted of Thermon sistance cables installed in channels around the flowline d under a layer of polyurethane insulation of 2.54 cm thickness. Three cables, each having a rated output of W/m, were installed to provide over 200% of the oretical heat requirement.

The alternate flowline was equipped with Skin Effect rrent Tracing (SECT), a relatively new development the heating of flowlines. A small diameter conduit s welded continuously along the flowline and alternat- current was passed directly through the metal of the nduit. The concentration of current along the inside of conduit produces the desired heat. The SECT system, ich had not previously been utilized in industry for gh pressure gas service, shows much promise for the ating of long flowlines.

An instrumentation package provided strain gauges the flowline plus temperature and pressure sensors in region close to the wellhead. The signals from the nsors were converted by a Remote Transmission Unit TU) in the outer end of the flowline bundle and the ormation was transmitted by hard wire back to a adout station on shore.

After a short flow for cleanup, utilizing the rig uipment, complete control of the wellhead was estab- hed from shoreline facilities through the hydraulic ntrol lines. Following removal of the drilling rig to ner exploration drilling activity, an extended test of the ll was completed to establish an open flow potential of me 9 million m^3/day.

15. TRANSPORT

Two principal plans are being pursued to transport gas m the Arctic Islands. The Polar Gas Project contem- ates a large diameter pipeline across the ocean channels between the islands and down the West side of Hudson Bay to tie into existing pipelines in southern Canada. The initial throughput of the pipeline would be 60 million cubic m per day and the construction cost is estimated at 6.1 billion dollars in 1976 dollars. Gas reserves required to support the pipeline project are of the order of 420 to 507 billion cubic m. Presently discovered reserves are 360 billion m^3; continued exploration will be required to develop the reserves necessary for support of the pipeline project.

The Polar Gas Project has been developing the technology and identifying the environmental requirements for the pipeline project since 1972 and has expended over 60 million dollars in this effort. The principal area requiring technology development is the pipeline crossings of the ocean channels between the islands and to the Canadian mainland.

Panarctic has established the usefulness of ocean ice for ice platform drilling and for the transportation of heavy equipment by oilfield trucks. Using the ice to facilitate construction of marine pipeline crossings is a natural extension of the Panarctic experience. An intensive program was undertaken to learn about ice. Ice thickness was physically measured and strength and mechanical properties of ocean ice were measured by cutting slots in the ice and loading the ice in various fashions.

Using seismic equipment ice thickness and water depth were measured with tracked vehicles or helicopters in the less accessible areas. In open water areas during the summer time, ships were utilized to measure water depths and to obtain cores of the bottom sediments. Measurements of the roughness of the bottom of the ice have been taken with side scan sonar, and a modified conventional ditcher has been tested for its ability to trench cleanly through ocean ice up to 5 m in thickness.

Four methods of constructing channel crossings have emerged. Depending on the length of the crossing, bottom sediments and the competency of ice cover, each of the various systems offers particular advantages. Where the ice is strong and the crossing is long, a method was developed to pull the pipeline along the bottom of the ocean with winches supported on the ocean ice in a manner similar to that described for the Drake completion.

For short crossings a shore-to-shore bottom pull can be employed and for longer crossings, where the ice is not sufficiently competent, the laybarge method will be employed in the summer period of open water. A tunnel has been proposed for one short crossing where other methods are not applicable.

An alternative scheme, proposed by Petrocan, the Government oil company, visualizes the transport of liquified natural gas from the Arctic in a year-round operation utilizing ice breaking LNG vessels. Such a scheme would be initiated as a pilot project delivering, in the first instance, some 7 million m^3 per day to the eastern seaboard of Canada. Such a scheme has the merit of offering an opportunity to initiate operations on a relatively small scale with a capacity for expansion as the efficiency of the system is established and as markets are developed.

16. CONCLUSION

The development of an economic ice platform drilling system to explore for offshore petroleum resources in the Canadian Arctic Islands has been an important part of the exploration process. The demonstration of a viable system for the completion and production of a subsea well under the ice constitutes a second important step in the exploration and the development of petroleum resources in the Canadian Arctic.

Refinement and further development of the offshore drilling and production systems, plus investigation and study of methods for delivery to markets, are continuing coincident with an exploration program that is establishing the presence of large hydrocarbon accumulations in a lightly investigated but important geological province which offers much promise for the provision of substantial reserves of hydrocarbons.

Date Due

46514 Pam:622.24:(*460)
HET

HETHERINGTON, C.R. and FRANKLIN, L.J.
Offshore drilling and production in deep ice covered waters

DATE LOANED | BORROWER'S NAME | DATE DUE

46514 Pam:622.24:(*460)
HET

HETHERINGTON, C.R. and FRANKLIN, L.J.
Offshore drilling and production in deep ice covered waters

BOREAL INSTITUTE FOR NORTHERN STUDIES, LIBRARY
THE UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA T6G 2E9
CANADA

University of Alberta Library
0 1620 0335 7397